HYDICE: OPERATIONAL SYSTEM STATUS

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ABSTRACT

We report on the present status of the Hyperspectral Digital Imagery Collection Experiment (HYDICE), which has now been operational for nearly a year.

1. INTRODUCTION

HYDICE is a program to field a state-of-the-art imaging spectrometer to support utility studies of high spectral resolution measurements in the 400-2500 nm range. The program was initiated by the U. S. Congress to investigate the application of hyperspectral data to the needs of federal agencies (forest assessment for the U.S. Department of Agriculture, mineral exploration for the U. S. Geological Survey, and so forth). To meet these objectives, an airborne imaging spectrometer was designed with the intent of achieving substantial improvements over existing systems in the areas of spatial resolution, sensitivity, and accuracy of absolute calibration. The sensor was built by Hughes Danbury Optical Systems, Inc., and integrated into a Convair 580 operated by the Environmental Research Institute of Michigan (ERIM).

The HYDICE sensor made its first data collection flight on 26 January 1995. A series of test flights culminated in a joint calibration exercise with AVIRIS, in June 1995, over Cuprite NV (plate 1, attached at the end of the paper), Ivanpah Playa CA, and Lake Tahoe. Since then, the sensor has been used in a quasi-operational mode, in which data collection was combined with additional sensor characterization exercises. The system has had a total of 27 flights to date, collecting half a terabyte of data.

2. SYSTEM OVERVIEW

The HYDICE sensor is a pushbroom imaging spectrometer that uses a biprism dispersing element and a two-dimensional focal plane array to enable a single optical path design. The array is a 320 X 210 element InSb array fabricated by Hughes Santa Barbara Research Center, with multiple gain regions and passivation to support operation over the full 400 - 2500 nm spectral range. The array is electronically shuttered with a fixed read time of 7.3 msec. The frame rate can be adjusted from 8.3 to 50 msec, allowing one to use nearly the full range of V/H ratios within the flight envelope of the CV 580. In particular, the altitude range from 5,000 to 25,000 feet can be used to achieve spatial resolutions from 0.8 to 4 meters. Calibration is done in-flight through the full optical system, and is referenced to a ground standard that is tied to U. S. National Institute of Standards and Technology and U. K. National Physical Laboratory standards.

A detailed description of the initial system design was published in an earlier ISSSR paper1. Laboratory performance tests of the focal plane subsystem and the ultimately deployed version of the full sensor system have also been published2,3. Finally, a detailed overview of how the system is used in normal operations is now in press4. Accordingly, we will not discuss these aspects further in this paper.

3. FLIGHT PERFORMANCE

An important part of the first year's data collection has been experiments to characterize the in-flight performance characteristics of the full HYDICE system, and to discover and define any anomalies. The primary focus of this characterization effort is the radiometric accuracy of the data; but, the system MTF, spectral calibration, SNR, and stray light performance are also being investigated. The joint HYDICE/AVIRIS collections referred to above, which included extensive ground truth measurements, are an important data source; one of the results of the Ivanpah Playa over flight is published elsewhere in this volume5. In addition, the HYDICE calibration standards have been intercompared with radiance standards from JPL and the University of Arizona. A final report of this characterization effort is expected in April 1996.

Some initial, very encouraging results can be reported for the system signal-to-noise ratio. In the original system specifications1, a design radiance spectrum was specified for the evaluation of the SNR. This radiance spectrum is derived from a MODTRAN calculation for a reflectance target of 5%, a solar zenith angle of 60o, and a midlatitude summer atmosphere. It is an extremely stressing standard, intended to ensure sufficient sensitivity for observations of water, normally a very dark target.

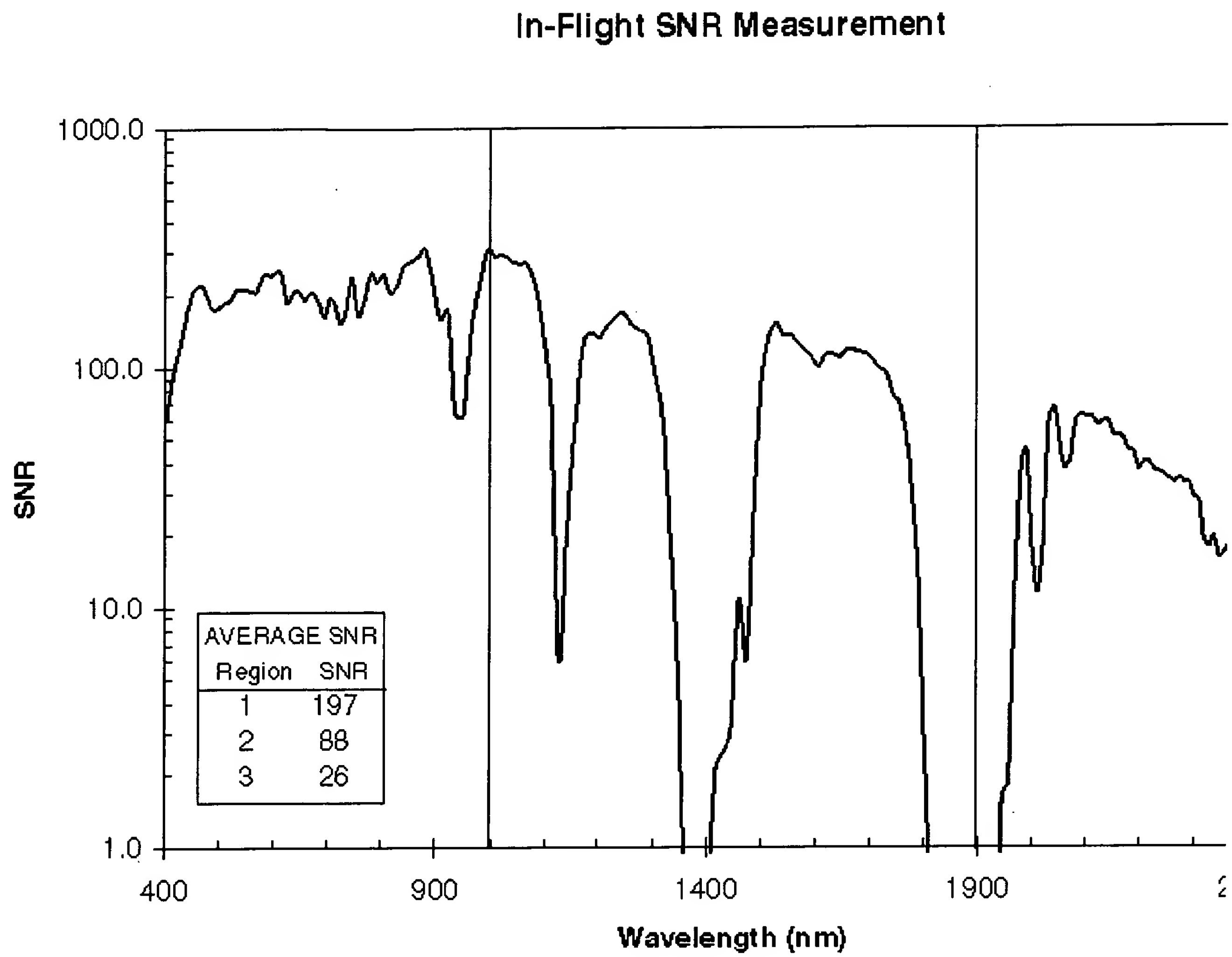

Figure 1. HYDICE in-flight SNR on March 1. The data are referenced to the design radiance standard, corresponding to a 5% reflectance target and a solar zenith angle of 60o.

Figure 1 shows one measurement of the in-flight, full system SNR. The data were taken from FCU measurements during the March 1 flight over Ann Arbor. The signal was scaled by the ratio of the design radiance to the FCU radiance, in order to reduce it to the design standard. The SNR was computed from (<signal+background> - <background>)/s.d.(signal+background), taking averages over 50 minor frames and all spatial samples. The average SNR values tabulated in the figure are for the spectral ranges from 400-1000 nm, 1000-1900 nm, and 1900-2500 nm, corresponding to the three spectral regions defined in the original design1.

Included in the joint AVIRIS/HYDICE over flights were measurements of Lake Tahoe, a very dark water target. Observations were made of a region of the lake that included a small boat (visible in the HYDICE image) from which simultaneous measurements of the water-leaving radiance were made. Figure 2(a) shows the radiance levels retrieved from six cuts across the HYDICE deep water scene. The radiances range from 1/3 to 1/4 of the design radiance spectrum, corresponding to reflectances ~ 2% at 500 nm. Figure 2(b) shows the SNR calculated from the mean and standard deviation of 2500 pixels in the scene. Note that the HYDICE data have an SNR ~ 70 for the ~2% reflectance region! Figure 3

shows the comparison between the water-leaving radiances retrieved from the HYDICE scene and those measured *in situ*. The agreement is generally quite good, with the major deviation (at 450 nm) attributable to incorrect calibration of the FPA scratch.

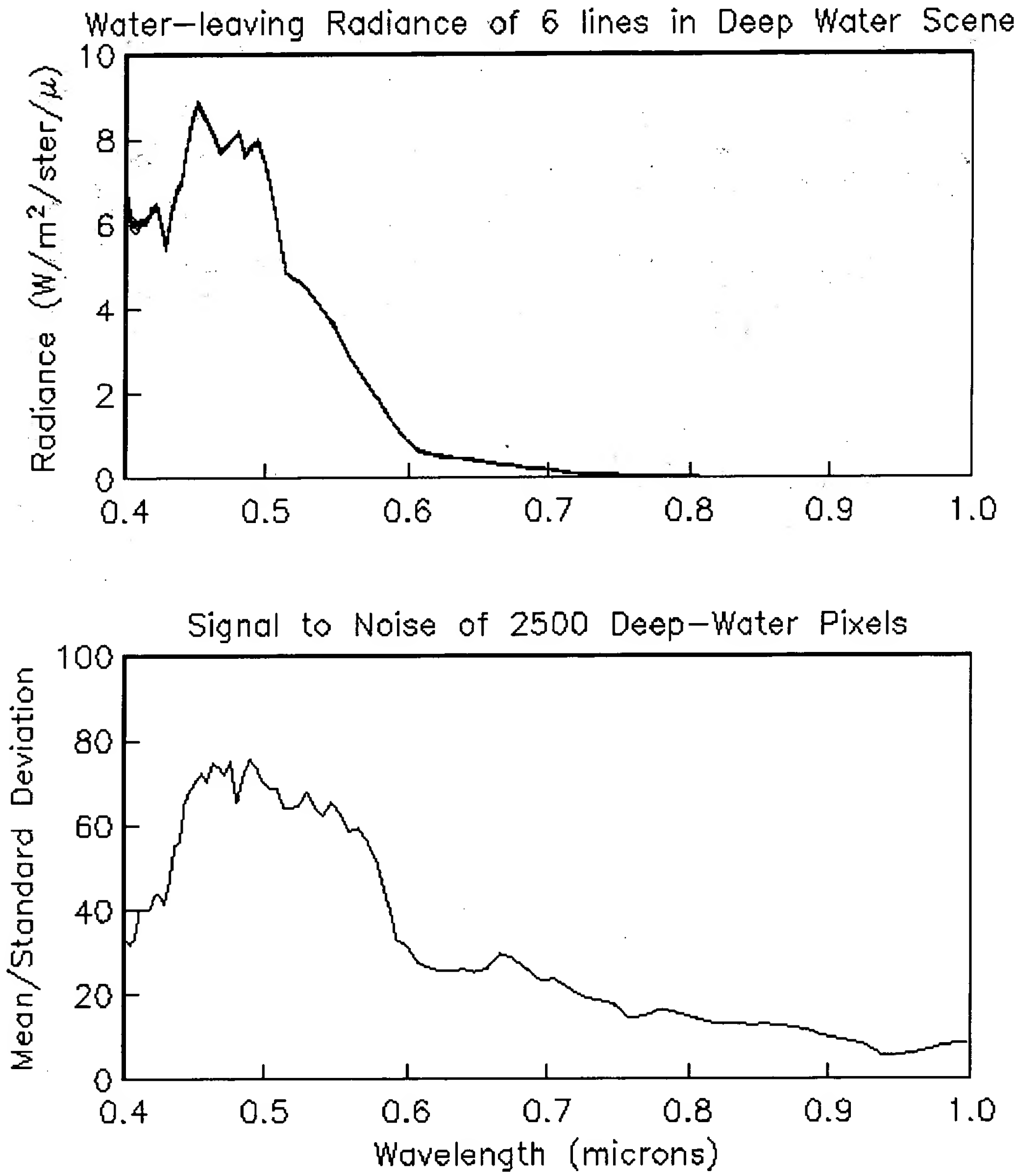

Figure 2. (a) Water-leaving radiance retrieved from HYDICE measurements of Lake Tahoe. (b) HYDICE SNR over Lake Tahoe. The data are calculated from 2500 deep water pixels in the HYDICE scene.

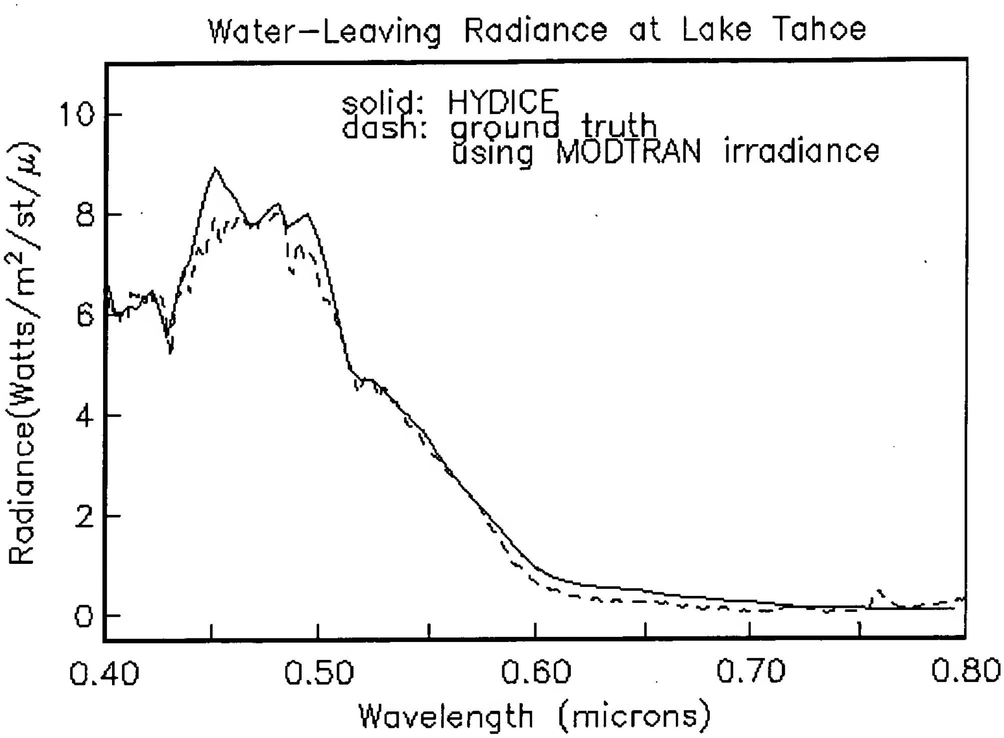

Figure 3. Comparison of HYDICE and *in situ* radiances. The water-leaving radiances retrieved from HYDICE measurements of Lake Tahoe are shown in the solid line. The water-leaving radiances determined *in situ*,

using a MODTRAN calculation to define the solar irradiance, are shown in the dashed line.

As said above, the report of the initial characterization activity is still being completed. In fact, we expect that characterization and refinement of the data product will be an ongoing process. However, we can certainly say that, after nearly a year of operations, with field experiments having been conducted since June, HYDICE has demonstrated its operational flexibility and has performed generally as predicted from the laboratory testing. There are no significant hardware malfunctions, although some system debugging is still required. Some blemishes have been identified in the data; but algorithms are being developed to remove them and, in many cases, have already been successfully demonstrated.

4. ACKNOWLEDGMENTS

We wish to thank the many people who have contributed to the development of the HYDICE sensor, as listed in the acknowledgements to references 1-3. We also thank W. J. Rhea (NRL) for the *in situ* radiance measurements at Lake Tahoe, and A. Clegg (NRL) for assistance in preparation of plate 1. As always, we acknowledge our appreciation of Mark Landers (Department of the Navy) and John Colwell (SAIC) for their tremendous work in the initiation and promotion of the HYDICE program.

5. REFERENCES

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6. COLOR PLATES

Plate 1. HYDICE and AVIRIS images of Cuprite NV. The AVIRIS image is 10 km X 15 km; the HYDICE image is 1 km X 1 km. Both images are three-color composites of selected individual bands in the visible.